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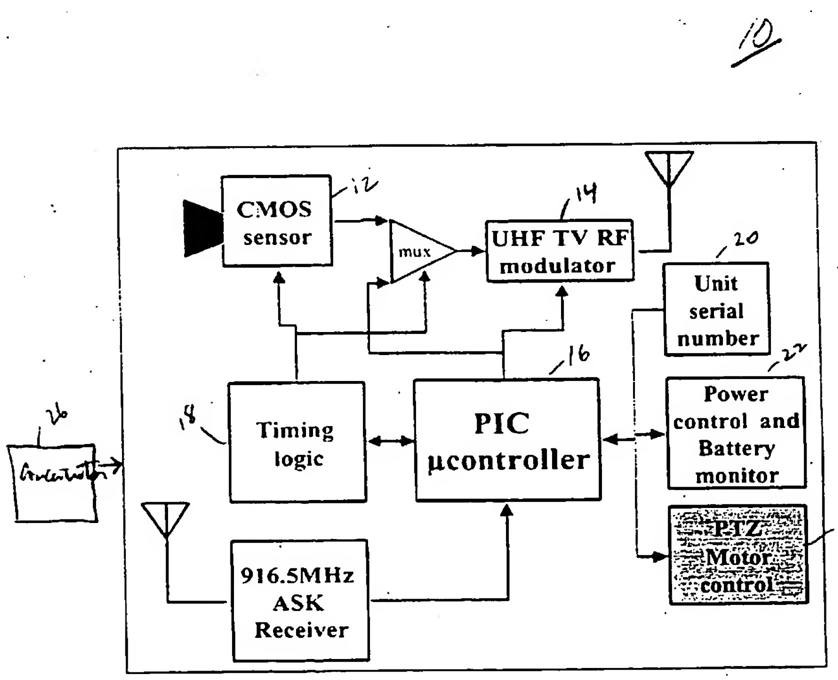
(54) Title: MULTIPLEXED WIRELESS PAN AND TILT CAMERA ARRAY




(57) **Abstract:** A system of multiplexed, wireless, battery powered video cameras (10) and an RF video receiver, video digitizer, de-multiplexer and video compressor is disclosed. Also disclosed is a design for reducing the effects of fluorescent lighting flicker on motion sensitive video compression algorithms such as MPEG (42). Also disclosed is a design for a remote controlled electro-mechanical pan and tilt mechanism (60) with a single moving part per axis that allows precise positioning and variable slow rate.

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# MULTIPLEXED WIRELESS PAN AND TILT CAMERA ARRAY

## TECHNICAL FIELD

This invention relates to remote viewing of multiple video cameras in a closed circuit environment as well as remote viewing over the Internet. In particular, this invention relates to the short range wireless transmission of video from multiple cameras multiplexed over a single radio frequency ("RF") television channel to a television receiver, digital video decoder, digital video demultiplexer and digital video compression engine.

The invention also includes a design to reduce the effects of flickering fluorescent lights on video compression algorithms such as MPEG. The invention also includes a remote controlled electro -mechanical pan and tilt system to aim the cameras.

## BACKGROUND

Closed Circuit Television (CCTV) systems are commonly used in security and remote monitoring applications. These CCTV systems are usually analog systems where remote viewing requires the transmission of the camera analog video over dedicated coaxial cables. Many commercial and private users require multiple cameras to be simultaneously viewable from a given site. The installation of multiple wired cameras requires significant labor to run coaxial video cables and power cables between the multiple cameras and the camera controller and display.

Recently the Internet has developed to the point where highly compressed digital video may be transmitted from anywhere and to anywhere in the world. Cameras and computers that provide digital video to the Internet and the World Wide Web are commonly called Web-cams.

Computers that contain video digitizers, video compressors and the network interface equipment are replacing the traditional analog CCTV camera controllers. When used in multiple camera applications these systems still require the labor-intensive installation of coaxial and power cables between the cameras and the video digitizers in the camera computer system. A means of wirelessly connecting multiple cameras to the camera controllers is needed.

Many wireless camera systems are currently available that use a few limited radio bands authorized by the FCC in the Industry Scientific and medical radio bands known as ISM. The unlicensed ISM bands are regulated by the FCC to short range (typically less than 1000 ft) and relatively low power levels. Due to the large bandwidths required by analog video, typically about 6MHz per channel, and the use of Frequency Modulation (FM) to reduce the effects of radio frequency noise only four analog TV channels are practical in the 2.4GHz ISM bands. In addition, four separate receivers and decoders are required in existing four channel systems to allow simultaneous viewing of four cameras. Existing wireless systems then are limited to only four wireless cameras in the 2.4GHz ISm band that is insufficient for many applications. Some existing wireless camera systems use standard X10 household power controllers to allow multiple cameras to share the same RF channel. Only one of the cameras is turned on at a time by remote control over X10 household wiring protocols. These systems are limited to viewing one camera at a time. An invention that allows access to and real time viewing of greater than four wireless cameras is needed.

Most cameras use standard television system timing and signal levels such as the North American NTSC standard which sends 30 frames of video per second made up of 60 interlaced fields of odd numbered and even numbered video scan lines. At 30 frames per second television video appears to be a smooth flow of motion due to the persistence of the human vision system.

The present state of the art for Internet communications technology limits the amount of affordable bandwidth that can be applied to motion video. Digital video compression techniques such as JPEG and MPEG help to reduce the Internet bandwidth limitations somewhat but still typically result in much less than 30 frames per second at reduced resolution over a standard phone modem. The uses for Internet video are such that a limited frame rate is acceptable in most applications. Many present web-cams and web video servers transmit live video at rates from 30 frames per second to several seconds per frame.

MPEG compression relies in part on detecting motion in the image and transmitting the motion vectors instead of the entire image. The MPEG motion compression scheme is sensitive to the flickering light produced by most fluorescent lights. Flickering fluorescent lights cause the MPEG motion compression algorithms to waste bandwidth by interpreting

the flickering lights as motion. An invention is needed to reduce or eliminate the effects of fluorescent lights on MPEG motion sensing compression algorithms.

Camera systems frequently include an electro mechanical system to rotate and elevate the camera in order to adjust the camera view remotely. This camera movement is called "pan and tilt". Most existing pan and tilt systems use electric motors and a complex and costly system of reduction gears to reduce the high-speed electric motor to the low speeds needed to pan and tilt the camera. Typically the camera assembly is mounted on a pan and tilt base unit and the entire camera is panned and tilted. The existing geared electric motor systems also suffer from inaccurate positioning due to slack in the gear trains known as lash. An invention is needed that provides a much simpler, less costly and more precise means of camera positioning.

## SUMMARY

In an aspect, the invention features a battery-powered wireless video camera system including means for supporting multiple wireless video cameras with electromechanical pan and tilt functions and a lighting compensation subsystem.

Embodiments of the invention may have one or more of the following advantages.

A method for multiplexing wireless video and data transmissions using time division multiplexed transmission of analog video over a single radio frequency (RF) frequency modulated (FM) video channel. Multiple wireless cameras are synchronized by a low bandwidth, low power transmitter in a central camera receiver concentrator called a back channel. The back channel transmitter contained in the receiver concentrator uses Amplitude Shift Keying (ASK) or Frequency Shift Keying (FSK) modulation techniques to transmit digital synchronization, slot timing, pan and tilt and zoom commands to the individual cameras. The cameras may be addressed uniquely or as a group depending on the command type and camera address identifiers contained in the back channel data stream. Microprocessors in each camera receive video synchronizing and control commands from the back channel transmitter in the central receiver concentrator. Each camera is programmed via the back channel to transmit one or several fields of analog video at specific points in time called slots within a preprogrammed contiguous sequence of slot times called a master frame. The analog video RF transmitters in each camera are turned on and off at precise

points in time corresponding with the middle of the last video line of a video field. When one camera stops transmitting another starts at the same point in time. The protocol dictates that only one transmitter is on during any slot time. The video RF receiver in the receiver concentrator will see a continuous sequence of video fields appearing as one continuous RF transmission.

Each camera contains a 48 bit electronic serial number that uniquely identifies that camera. The serial number is encoded in the last video line of every field by the camera microprocessor. An analog multiplexer in the camera switches between the analog video from the camera chip and the digital serial number generated by the microprocessor during the last video scan line of each field. The switch control for the analog multiplexer is controlled by the CPLD that tracks the camera chip timing. The analog multiplexer switch control signal also interrupts the microprocessor to cause it to transmit the serial number in a bit serial manner to the analog multiplexer which outputs the digital serial number to the analog video RF transmitter. The microprocessor clock is synchronized to the camera chip clock and the CPLD clock to allow it to transmit the serial number within one video scan line time.

The receiver concentrator receives the analog video via the analog video RF FM receiver as a continuous analog video stream made up of video field sequences from multiple cameras. The FM modulation scheme used for the analog video transmission allows the RF FM receiver to be insensitive to the varying signal strengths that result from multiple transmitters time-sharing one RF channel. The RF FM receiver output signal level is a function of the frequency deviation transmitted by the RF FM analog video transmitters in each camera and not the varying signal strengths due to varying distances between the various cameras and the receiver concentrator. The analog video is decoded by an analog video decoder chip such as a Philips SAA7110 video decoder, which converts the analog video into a digital video stream, which is captured and stored in memory contained in the receiver concentrator. The microprocessor in the receiver concentrator reads the last scan line in each captured field to extract the camera serial number. The microprocessor uses the serial numbers to de-multiplex the video fields into separate buffers associated with each camera. The microprocessor in the receiver concentrator then digitally compresses each camera's video buffers using software video compression or a video compression chip.

Industry standard digital video compression techniques such as JPEG, JPEG2000, MPEG1, MPEG2 or MPEG4 may be used. This scheme allows a single video decoder chip and single compression resource to be shared by multiple cameras.

The receiver concentrator is programmed to transmit the compressed video stream from each camera to the requesting Internet client using standard TCP/IP protocols via a network control device contained in the receiver concentrator. Each Internet client receives compressed video only from the camera or cameras requested by it.

The microprocessor in the receiver concentrator may modify each video field from each camera to add a digital water mark and/or logo and/or copyright and/or time stamp that allows the client to record and/or identify the source and ownership of each video sequence. The digital watermark and/or logo may also be used to prevent or discourage the illegal use of the video images.

The RF FM transmitter in each camera is also used to transmit acknowledge signals back to the receiver concentrator in response to specific back channel commands. Data communication over the video RF FM transmitter from the camera to the receiver concentrator is referred to as the forward channel. The microprocessor in the camera inserts command acknowledge codes and/or camera status and/or data acquired from sensors and/or switches and/or low speed analog to digital converters in the same video scan line it uses to encode the camera serial number described in claim 2.

The microprocessor in the camera may use some or all the video scan lines to transmit high bandwidth digital information to the receiver concentrator. The high bandwidth data is acquired from analog to digital converters in the camera that digitize sound from a microphone in the camera. The high bandwidth data may also be acquired from external devices connected to the camera such as joysticks and/or position sensors and/or medical instrumentation. The camera may be programmed to transmit a mixture of low and high bandwidth digital data and analog video during different slot times.

The forward channel described in claims 6 and 7 allows local and remote network diagnostics to isolate system problems to a specific camera and to specific problems in the camera. The microprocessor in the camera may be programmed to generate a simple video test pattern to isolate camera video sensor chip problems from camera communication problems. Light emitting diodes (LEDs) in the camera may be turned on and off via

commands from the back channel to alert users to camera activity or failures. Buttons on the camera may be pressed to force a test of the camera and receiver concentrator and notify the user via the LEDs as to the status of the system.

Buttons on the camera may be used to alert a local or remote operator or program to user needs and/or emergency conditions.

An audible alert device in the camera may be activated by local or network control to gain the attention of anyone near the camera.

Heat sensors, smoke sensors, water leak sensors, temperature sensors and/or motion sensors in the camera may be used to notify local and/or network remote users or programs to safety and/or security related events.

The time division multiplexed nature of the camera design results in a low duty cycle for most of the camera components. The camera video sensor as well as the RF transmitter are off most of the time. The microprocessor in the camera powers down all unneeded resources between active slot transmissions. The microprocessor supports low power sleep modes and is programmed into low power sleep mode between slot transmissions that may be exited by wakeup timer resources in the microprocessor as well as wakeup commands from the receiver concentrator or by local events such as inputs from local sensors such as heat sensors, smoke sensors, water leak sensors, temperature sensors and/or motion sensors. These features allow the camera to be optionally powered by a battery for long periods of time.

A pan and tilt system implemented with a modified Sawyer type linear motor operating on long radius index rings or ring segments that move a first surface mirror mounted above the camera lens. Moving a lightweight mirror instead of the entire camera allows lower control forces and low energy requirements. The low energy attributes of this system are compatible with battery power sources. The long radius index rings amplify the motor torque and also allow fine grain movements of the camera view. The reversal of the image caused by the mirror is compensated for in the camera sensor chip by programming it to reverse the image scan sequence from the normal left to right. The Sawyer motor is implemented with a small permanent magnet that also provides zero power holding force. The complete pan and tilt system is implemented with two moving parts that may be implemented with low cost plastic molded parts with ferrous metal index ring segments. The

microprocessor in the camera receives pan and tilt commands from the receiver concentrator and translates these commands to precise motor control signals to the four coils in the modified Sawyer motor. Acceleration and deceleration profiles are implemented in the microprocessor software to provide smooth and precise camera positioning.

A system to reduce the effects of lighting variation caused by fluorescent lights. The light output from fluorescent lights varies at a 120Hz rate based on the national power grid 60Hz AC timing. NTSC video timing uses 59.97 Hz frame rates. Modifying the video timing to be exactly 60Hz frame rate will reduce the frame-to-frame image intensity beat time to hours instead of minutes. Reducing the frame-to-frame intensity variations will improve the digital video compression rates when using temporal compression schemes such as MPEG.

A photo diode light sensor in the camera is read by the microprocessor in the camera to determine the ambient lighting intensity variations caused by fluorescent lighting. The light intensity variations are analyzed in firmware over a 16-millisecond period to determine the point in time when the lighting levels are most stable. The camera system adjusts the video frame and electronic shutter timing to correspond with the most stable light output during the 16ms frame capture time. This scheme combined with the scheme in claim 14 reduces frame-to-frame intensity variations caused by fluorescent lights. Reducing the frame-to-frame intensity variations will improve the digital video compression rates when using temporal compression schemes such as MPEG.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

## DESCRIPTION OF DRAWINGS

FIG. 1 is a block diagram of a multiplexed wireless pan and tilt camera.

FIG. 2 is a block diagram of a concentrator.

FIG. 3 is a graph of the basic analog time division multiplexing of the multiplexed wireless pan and tilt camera of FIG. 1.

FIG. 4 is a block diagram of a pan and tilt mechanism utilized in the multiplexed wireless pan and tilt camera of FIG. 1.

FIG. 5 is a block diagram of a pan and tilt linear motion operation of the multiplexed wireless pan and tilt camera of FIG. 1.

Like reference symbols in the various drawings indicate like elements.

## DETAILED DESCRIPTION

Referring to FIG. 1, a multiplexed wireless pan and tilt camera array 10 includes a CMOS sensor camera 12. The CMOS sensor camera 12 outputs analog NTSC video to the UHG TV RF modulator transmitter 14. The transmitter 14 is keyed by the microcontroller 16 to transmit only during the slot times commanded by a concentrator 26. The microcontroller 16 receives video synchronization pulses and slot timing commands via the 433MHz OOK (On Off Keyed) receiver. The timing logic block 18 tracks the camera line and frame timing and is also synchronized by the transmitted synchronization pulses from the concentrator 26.

The unit serial number block 20 is a serial memory device that contains a 64 bit unique serial number assigned to each camera 10 manufactured. The microcontroller 16 reads the serial number to determine the specific addresses it must respond to from the concentrator 26.

The power control and battery monitor block 22 contains the power sources and an analog battery level monitor that is read periodically by the microcontroller 16 to determine the condition of the battery. This block 22 also contains power switches that allow controlling power to the CMOS sensor 12, the OOK receiver and the delta sigma data acquisition blocks.

The PTZ motor control block 24 contains the motor drive circuits for the linear motors that control pan and tilt as well as the servo motor that controls the zoom lens.

The delta sigma data acquisition block contains a single bit analog to digital converter is clocked at a synchronous rate with the video clock. The output of this converter is stored into memory for later transmission at a higher synchronous rate during one or more slot times.

Referring to FIG. 2, the concentrator 26 (of FIG. 1) includes a high performance RISC (Reduced Instruction Set Computer) processor 30. This processor 30 handles real time digital live video capture from the Digital NTSC decoder 32 via the FPGA data formatter 34

and the 512X32 FIFO 36. The RISC processor 30 is connected with the 512X32 FIFO SDRAM memory 38, Flash memory 40, and MPEG/JPEG encoder 42. The OOK Xmitter 44 is the On Off Keyed back channel transmitter that transmits camera synchronization commands and time slot allocation commands to the multiple cameras. One of the optional blocks is a 100 bT Enet Internet interface 46 that allows the concentrator 26 to send digital video to the Internet.

Referring to FIG. 3, an analog time division multiplexing the basic analog time division multiplexing that the array 10 (of FIG. 1) is based on. During a one second time block, 15 time slots are allocated to the active cameras. Each time slot corresponds to 4 field times that make up two NTSC video frames. The time block duration and the number of fields assigned to each slot is a system dependent choice. Different time blocks and different number of fields per slot may be used to meet the system performance needs.

Referring to FIG. 4, a pan and tilt mechanism includes a pan index ring 60 attached to a mirror mount and tilt pivot 62 and may be driven through 180 degrees. The tilt pivot 62 is a modified Sawyer linear motor implemented as a 30 degree motor segment. The 180 degree base and 30 degree pivot may be implemented in any combination of degrees of movement from 0 to 360 degrees. This system has only two moving parts and the design may be varied by altering the index ring 60 or tilt pivot radius for different torque or positioning accuracy requirements.

Referring to FIG. 5, the pan and tilt linear motor operator includes a permanent magnet 80 with four legs and two sets of coils wound in such a way that different current direction will reduce the magnetic flux in one leg while reinforcing the flux in the other leg. The two coils are alternately driven with forward current. Reverse current or no current according to the current direction arrows shown.

Analog Time Division Frame Multiplexed Wireless Video

The present invention allows multiple wireless cameras sharing a single wireless TV channel to be viewed simultaneously by taking advantage of the inherent sequential framed nature of the NTSC TV standard. Rather than having a limited number of full bandwidth TV channels with one camera per channel, the present invention shares the 60 field per second field rate of a single RF channel of NTSC video between multiple cameras. A virtually

unlimited number of wireless cameras may be accessed and controlled in this fashion with a limitation of a total of fields per second shared amongst the active cameras. The multiple cameras are effectively multiplexed in a time division multiplexing scheme using the 60 field per second NTSC signal. Each active camera turns on its transmitter at pre-programmed points in time that correspond with specific field numbers in the NTSC video signal.

Dynamic Camera selection and Frame Rates

Resource scheduling software in the Camera Controller determines which cameras must be accessed and at what field rates. The camera selections and field rates may be adjusted dynamically based on real time events such as motion detection or a change in the viewing demands of the users.

Wireless Digital Synchronization and Control Back-channel

A means of synchronizing the wireless cameras is needed so that each camera knows when to turn on its transmitter to insert its video fields or frames into the RF NTSC video sequence. This synchronization is achieved by use of a low speed digital radio link between the camera controller and all of the cameras. This digital radio control channel is called the back-channel. The camera controller has a simple On Off Keyed (OOK) transmitter. Each camera has a simple OOK RF receiver that receives the synchronization and control information transmitted by the camera controller. Each camera also has a unique digital serial number that allows the camera to be uniquely addressed and programmed by the camera controller via the RF back-channel with the specific time slot or slots that it must transmit its video frames. The back-channel is used for the following functions:

- Sending video timing synchronization pulses to all cameras
- Sending field slot commands to each camera
- Sending firmware updates to the microprocessor in each camera
- Sending commands and settings for the CMOS sensor in each camera
- Sending position information to the pan and tilt system in each camera
- Sending diagnostic commands to the cameras to identify problems or failures
- Sending commands to control other external resources in the camera such as LED indicators or infra-red LED scene illumination.

Once all of the cameras are individually programmed with their field slot sequences via the back channel, the camera controller transmits a continuous stream of synchronizing pulses that are received by all of the cameras. The synchronizing pulses are used in each camera to establish a field zero reference point. The cameras then turn on their video transmitters during their respective pre-programmed field time slot numbers. In this way, a continuous series of fields are broadcast from the array of cameras such that the TV RF receiver in the camera controller sees a composite signal made up of the multiple fields transmitted by the camera array.

Video Amplitude Modulation Transmission

Broadcast TV uses Amplitude Modulation (AM) with 6MHz channel spacing in a variety of radio bands. AM video transmission suffers from sensitivity to fluctuations in received signal strength as well as susceptibility to random noise such as auto ignition or electrical motors. The advantage to AM transmission is a somewhat simpler transmitter that requires only a 6MHz bandwidth allocation as well as readily available receivers such as those used in TVs and VCRs. When using AM transmission video for the MWC the receiver must always produce the same video output levels so as to not introduce a signal discontinuity when different cameras switch their transmitters on and off. All TV receivers include RF Automatic Gain Control that adjusts the gain of the RF receiver to compensate for variations in received signal strength. These AGC circuits typically require tens of milliseconds to adjust to a sharp change in RF strength. This AGC function is typically too slow to allow the receiver to adjust to different transmitters in the MWC.

Video Receiver Gain Compensation

The TV RF receiver in the camera controller will see different RF signal strengths for each camera due to the different distances between the individual cameras and the TV receiver. To compensate for the varying RF signal strength between cameras, the camera controller will adjust the gain setting of the TV receiver on a slot by slot basis. During the initial system start up of the camera controller, a camera calibration process measures the RF signal strength received from each camera and computes a corresponding receiver gain setting required to normalize the received signal for each camera. As each camera transmits

video fields during its time slots, the camera controller uses the pre-computed gain setting for the active camera to allow the receiver to output a signal with constant amplitude relative to the other cameras.

Video Frequency Modulation Transmission

Most existing wireless cameras use Frequency Modulation (FM). The advantage of FM is its relative immunity to signal strength variations and random noise. The disadvantages to FM video transmission are a somewhat more complex transmitter, the need for custom designed receivers, and its greater bandwidth requirements of about 15MHz. Most currently available wireless cameras use FM video modulation with a 3MHz carrier deviation and 15 MHz channel spacing. This results in 2 channels available in the 900 MHz ISM band and 4 channels in the 2.4GHz ISM band.

The use of FM video transmission in the MWC results in far more accurate video signal levels in the receiver output. This is essential to reduce the video signal discontinuity that results when different cameras switch on and off. The video decoder must see a consistent blanking level and synchronization signal level when switching between cameras. FM offers the most robust and low noise transmission system for the MWC and is the preferred implementation.

Transmitter Switching Timing

The MWC cameras are closely synchronized and the point in time when one camera switches off its transmitter and another camera switches on is carefully chosen to reduce visible artifacts.

The video receiver will see a transient in the received RF signal when MWC cameras switch in and out. However, this transient is very short, on the order of several microseconds, and will be interpreted as a glitch in the received signal during the switchover point between cameras. The switch point is carefully timed to occur in the middle of the last line of a video field similar to the point in time when VCRs switch video heads during playback. This point in the video field ensures that the transient is not visible and allows the maximum settling time before the vertical synchronization portion of the next video field.

Video Decoding and De-multiplexing

In the concentrator the video stream is received by the receiver/tuner and converted to a digital video stream in the NTSC decoder. This stream is a composite on the frames from all the active cameras in the MWC array. The software running in RISC processor in the concentrator demultiplexes the frame sequence according to the prevailing slot allocation timing.

Shared MPEG encoder

The incoming video stream is demultiplexed into separate video buffers for each active camera. These separate video buffers are processed through the MPEG/JPEG encoder to produce separate compressed video streams that are then sent to the internet. Each compressed video stream may be sent to one or more clients on the Internet. In this fashion, one MPEG/JPEG encoder resource is shared between all the active cameras.

Fluorescent Lighting Compensation

Fluorescent lights are powered by 60Hz alternating current that causes the lights to flicker at 120Hz. National grid electric power is typically very accurate for frequency. NTSC color TV timing has a 59.97Hz frame rate that when combined with the 60Hz lighting produces a 0.03Hz beat frequency that corresponds to 33 second periods. Once every 33 seconds the camera output will vary slowly from light to dark. These brightness variations result in unnecessary picture encoding and wasted Internet bandwidth and cause the MPEG temporal compression algorithms to waste bandwidth by interpreting the flickering lights as motion. The Fluorescent Lighting Compensation system uses a three-part strategy to improve MPEG compression ratios.

1. Synchronize the camera timing and the camera controller timings to the local power frequency. Adjust the camera electronic shutter timing relative to the synchronized power cycle to correspond with the most stable light output of the fluorescent lights.

2. Use a photo diode in each camera to determine the optimum electronic shutter speed of each camera.

3. Use a calibrated white target in the field of view of each camera to normalize the contrast and brightness of each frame.

These techniques may be used individually or in combination to reduce the effect of varying intensity of fluorescent lighting.

Pan And Tilt

Most existing pan and tilt systems use geared motors and move the entire camera that may weigh several kilograms. The new system uses two partially implemented, large radius, modified Sawyer linear motors to move a mirror in horizontal and vertical planes above a fixed camera. A Sawyer linear motor is actually a linear stepping motor. The new system implements a modified Sawyer linear motor in a pie wedge shape with the axis point at the apex of the wedge. The radius is chosen to achieve the required torque and stepping resolution. The stator is implemented with a permanent magnet with four teeth and two drive coils while the moving pie wedge is made of low cost light weight plastic with a toothed ferromagnetic material strip mounted near the rim of the pie wedge. Two wedges mounted at 90 degrees to each other with a first surface mirror positioned above a fixed camera realize a complete pan and tilt system. This system has the following features:

- Very low cost
- Low mass for fast acceleration
- High precision stepping
- Variable slew rates
- Low drive energy requirements
- No holding power required

Data Transmission

The MWC RF video transmitter is designed to transmit NTSC analog video. The MWC needs a forward data channel to communicate camera status and to acknowledge certain commands. The RF video transmitter is used as a data transmitter in these cases. There are three types of data transmitted over the RF video transmitter.

1. Analog NTSC video data
2. Digital camera status and command acknowledgements
3. Digital delta sigma PWM encoded analog data

In all cases the normal NTSC frame timing and levels are adhered to. The camera status and digital signals are transmitted using analog video as the medium. This allows the NTSC decoder in the concentrator to process the camera status and digital information as normal video.

Delta Sigma Analog Data Acquisition

The MWC may be used to provide analog time division multiplexed signals from sources other then the video camera. Low bandwidth analog signals such as temperature, battery voltage, machine tool positioning, pulse beats, and low quality audio may be transmitted using the same techniques.

A simple single bit analog to digital converter technique encodes a delta sigma pulse width modulated (PWM) output. The acquisition clock for this converter is made to be synchronous with the video timing but at a slower rate. The synchronous PWM stream is saved in a FIFO memory and then read back at a higher rate and transmitted as an analog video frame but with the video signal modulated by the PWM stream. The ratio of capture clock timing o transmit clock timing is made to be in the exact ratio needed to transmit the real time data within one or more video slot times. As an example, if the capture clock is 100KHz and the system is programmed to use one slot time to communicate this data and if the number of slots per block is 15 then the transmit clock will be 1500KHz. In this way, a continuous stream analog data may be time division multiplexed using the same timing as normal video frames.

At the concentrator side, the IRSC processor receives the time compressed PWM stream and converts it to real time by playing it back with the same 150Hz clock that was used to capture it.

The bandwidth of this scheme is limited to low quality audio or low speed analog events.

A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

**WHAT IS CLAIMED IS:**

1. A battery-powered wireless video camera system comprising:
   means for supporting multiple wireless video cameras with electromechanical pan and tilt functions; and
   lighting compensation subsystem.

2. The system of claim 1 wherein the means for supporting multiple wireless video cameras comprises:
   synchronizing the multiple wireless cameras by a low bandwidth, low power transmitter in a central camera receiver concentrator.

3. The system of claim 2 wherein he central camera receiver concentrator comprises:
   amplitude shift keying (ASK) means to transmit commands to the multiple wireless cameras.

4. The system of claim 3 wherein the commands comprise:
   digital synchronization;
   slot timing;
   pan and tilt; and
   zoom.

5. The system of claim 3 wherein the cameras are addressed individually.

6. The system of claim 3 wherein the cameras are addressed as a group.

7. The system of claim 1 wherein the cameras comprise:
   a microprocessor interfaced to an ASK receiver, timing logic, power control and battery monitor, a sensor, and RF modulator, unit serial number and multiplexer; and
   a concentrator.

8. The system of claim 7 therein the unit serial number comprises:

a 48 bit electronic serial number that uniquely identifies the camera.

9. The system of claim 7 wherein he unique serial number is encoded in a last video line of every field.

10. The system of claim 7 wherein the multiplexer switches between analog video from a camera chip and a digital serial number generated by the microprocessor during the last video scan line of each field.

11. The system of claim 7 wherein a switch control for the multiplexer is controlled by a CLLD that tracks the camera chip timing.

12. The system of claim 11 wherein the switch control interrupts the microprocessor to cause the microprocessor to transmit the unit serial number in a bit serial manner to the multiplexer that outputs the serial number to the RF modulator.

13. The system of claim 7 wherein a clock in the microprocessor is synchronized to the camera chip and the CPLD clock to transmit the unit serial number within one video scan line time.

14. The system of claim 7 wherein the concentrator is programmed to transmit a compressed video from the multiple cameras to a requesting Internet client.

15. The system of claim 14 wherein the compressed video is transmitted using TCP/IP.

16. The system of claim 7 wherein the concentrator includes a means for modifying a video field from each camera to add additional information.

17. The system of claim 16 wherein the additional information is a digital water mark.

18. The system of claim 16 wherein the additional information is a logo.

19. The system of claim 16 wherein the additional information is a copyright.

20. The system of claim 16 wherein the additional information is a time stamp.

21. The system of claim 7 wherein the RF modulator transmits acknowledging signals back to the concentrator.

22. The system of claim 7 wherein the microprocessor uses video scan lines to transmit high bandwidth digital information to the concentrator.

23. The system of claim 7 wherein the camera further comprises:
an audible alert device that is activated to gain the attention of a user.

24. The system of claim 23 wherein the audible alert device comprises:
means for detecting a stimulus.

25. The system of claim 23 where the stimulus is heat.

26. The system of claim 23 where the stimulus is smoke.

27. The system of claim 23 where the stimulus is water leaks.

28. The system of claim 23 where the stimulus is temperature.

29. The system of claim 23 where the stimulus is motion.

30. The system of claim 1 further comprising:
a pan and tilt system.

31. The system of claim 30 wherein the pan and tilt system comprises:
a modified Sawyer type linear motor operating on long radius index rings or ring segments that move a first surface mirror mounted above a camera lens.

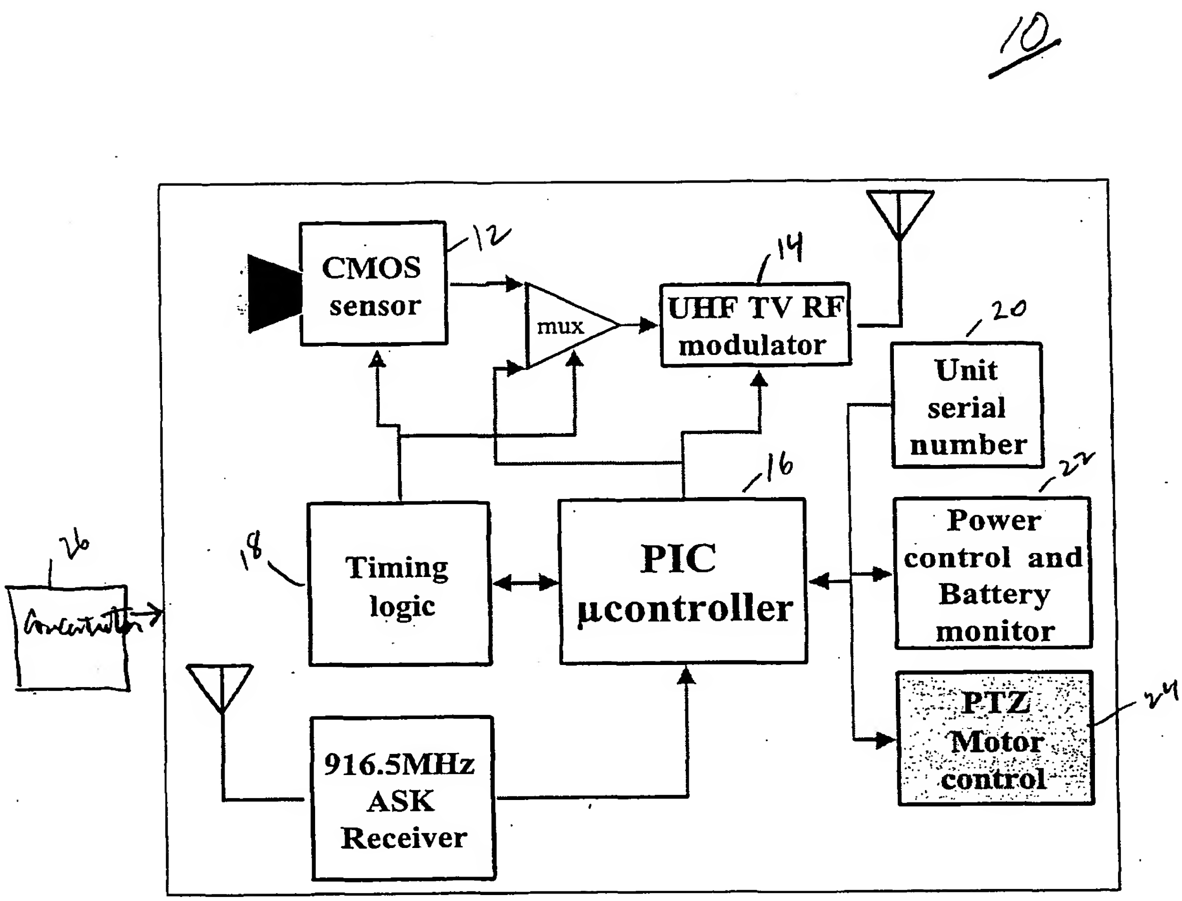
10
CMOS sensor
12
mux
UHF TV RF modulator
14
20
Unit serial number
16
22
Power control and Battery monitor
Timing logic
18
PIC µcontroller
26
Concentrator
916.5MHz ASK Receiver
PTZ Motor control
24

FIG. 1

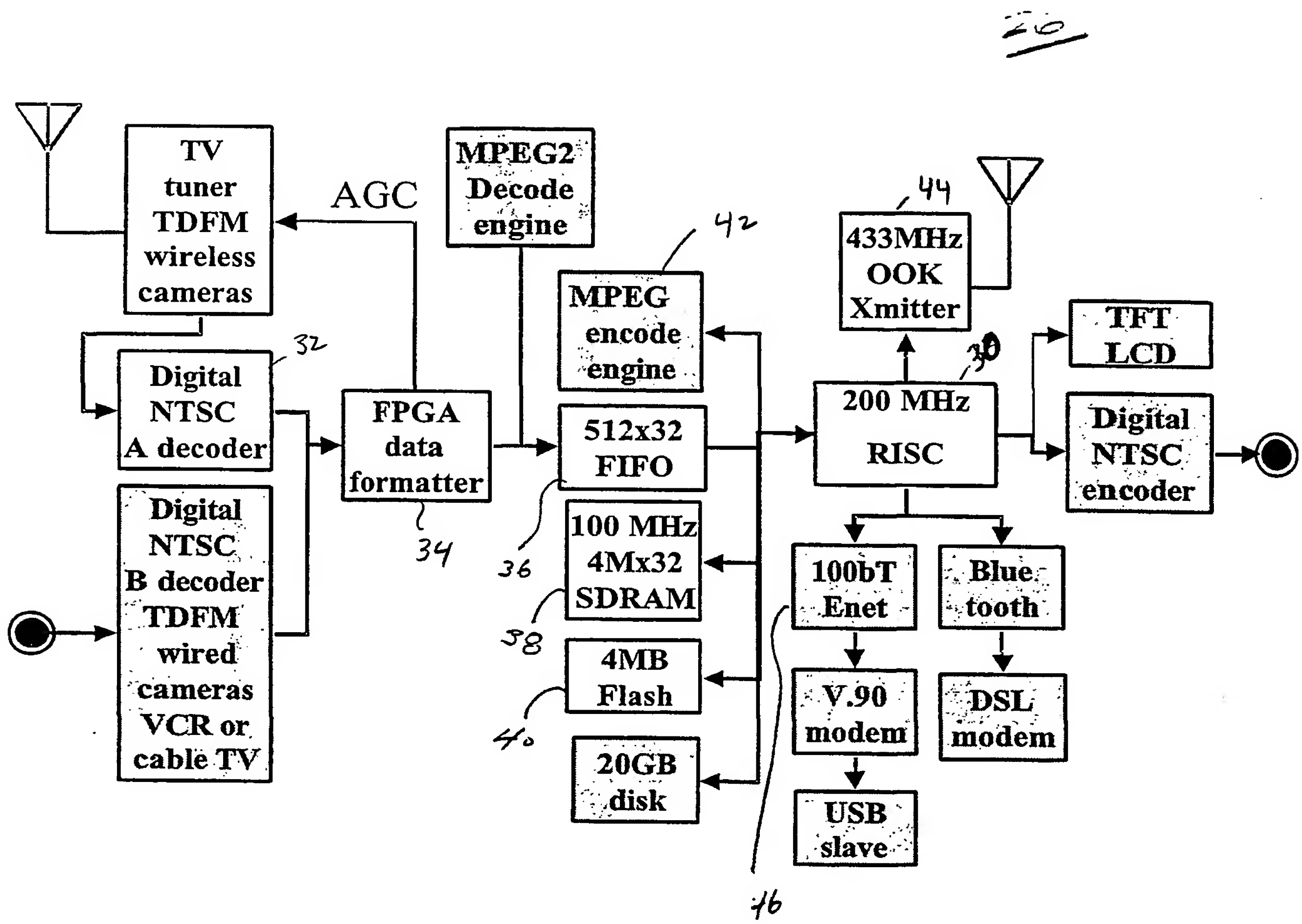
20
TV tuner TDFM wireless cameras
AGC
MPEG2 Decode engine
42
44
433MHz OOK Xmitter
MPEG encode engine
32
Digital NTSC A decoder
FPGA data formatter
512x32 FIFO
200 MHz RISC
30
TFT LCD
Digital NTSC encoder
Digital NTSC B decoder TDFM wired cameras VCR or cable TV
34
36
100 MHz 4Mx32 SDRAM
38
100bT Enet
Blue tooth
4MB Flash
40
V.90 modem
DSL modem
20GB disk
USB slave
46

FIG. 2

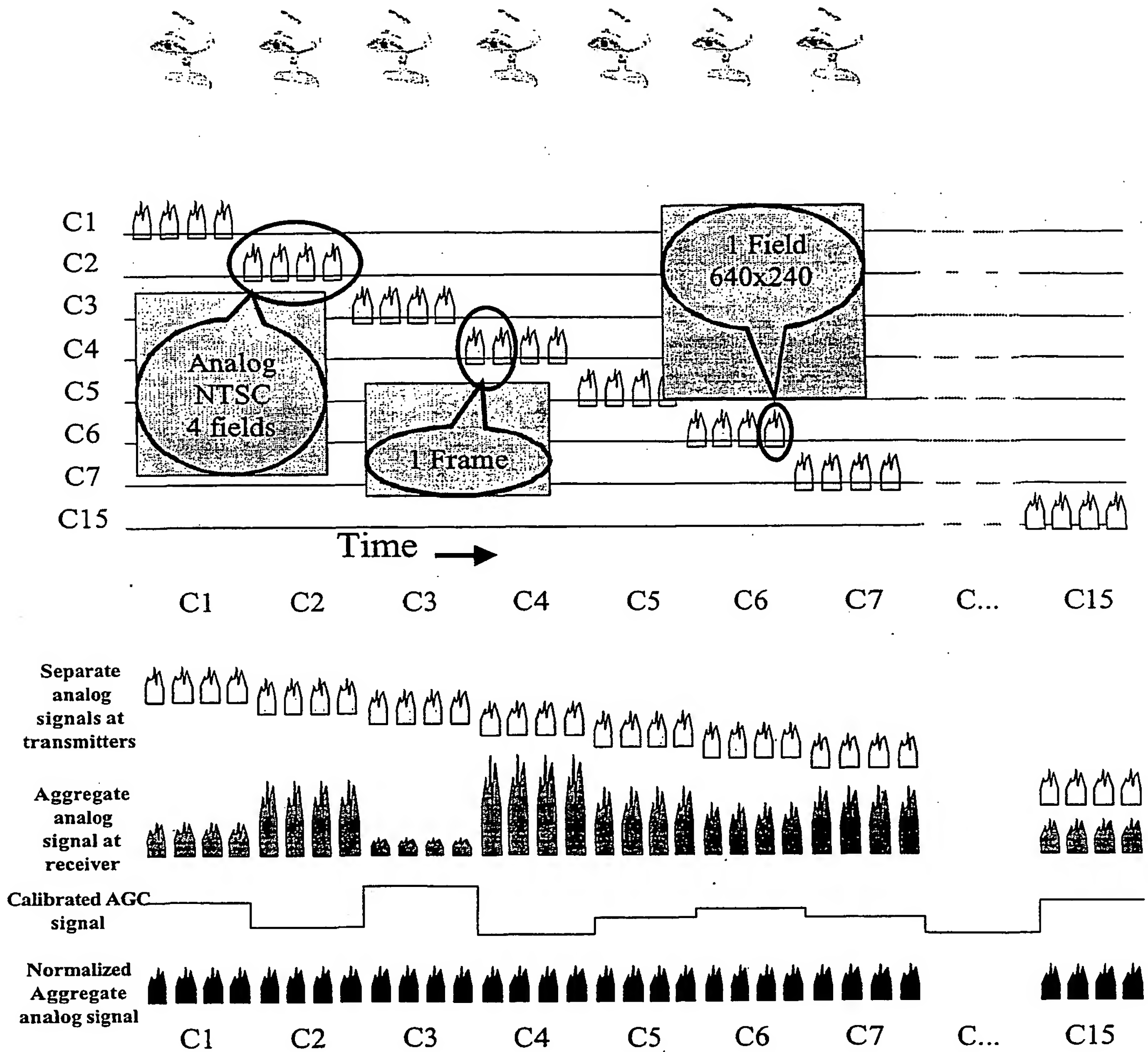
C1
C2
C3
C4
C5
C6
C7
C15
Analog NTSC 4 fields
1 Frame
1 Field 640x240
Time
C1 C2 C3 C4 C5 C6 C7 C... C15
Separate analog signals at transmitters
Aggregate analog signal at receiver
Calibrated AGC signal
Normalized Aggregate analog signal
C1 C2 C3 C4 C5 C6 C7 C... C15

FIG. 3

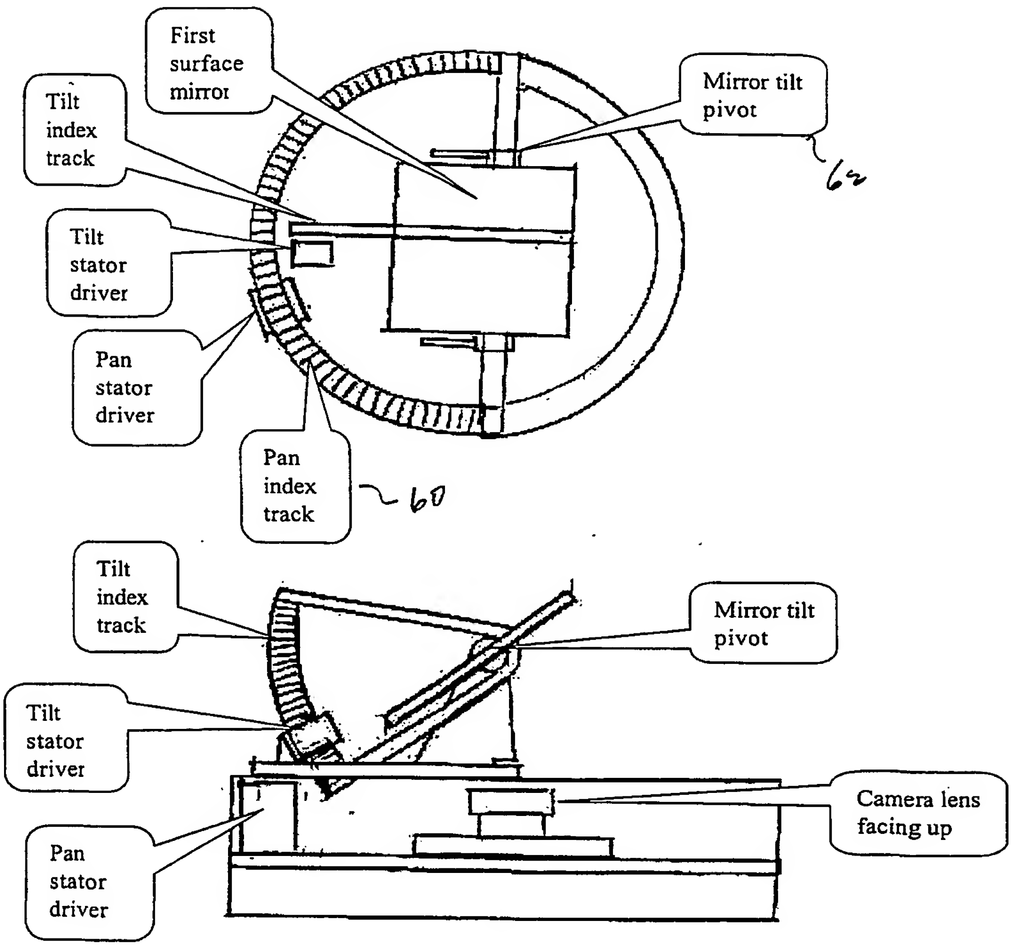
First surface mirror
Mirror tilt pivot
Tilt index track
Tilt stator driver
Pan stator driver
Pan index track
60
62
Tilt index track
Mirror tilt pivot
Tilt stator driver
Camera lens facing up
Pan stator driver

FIG. 4

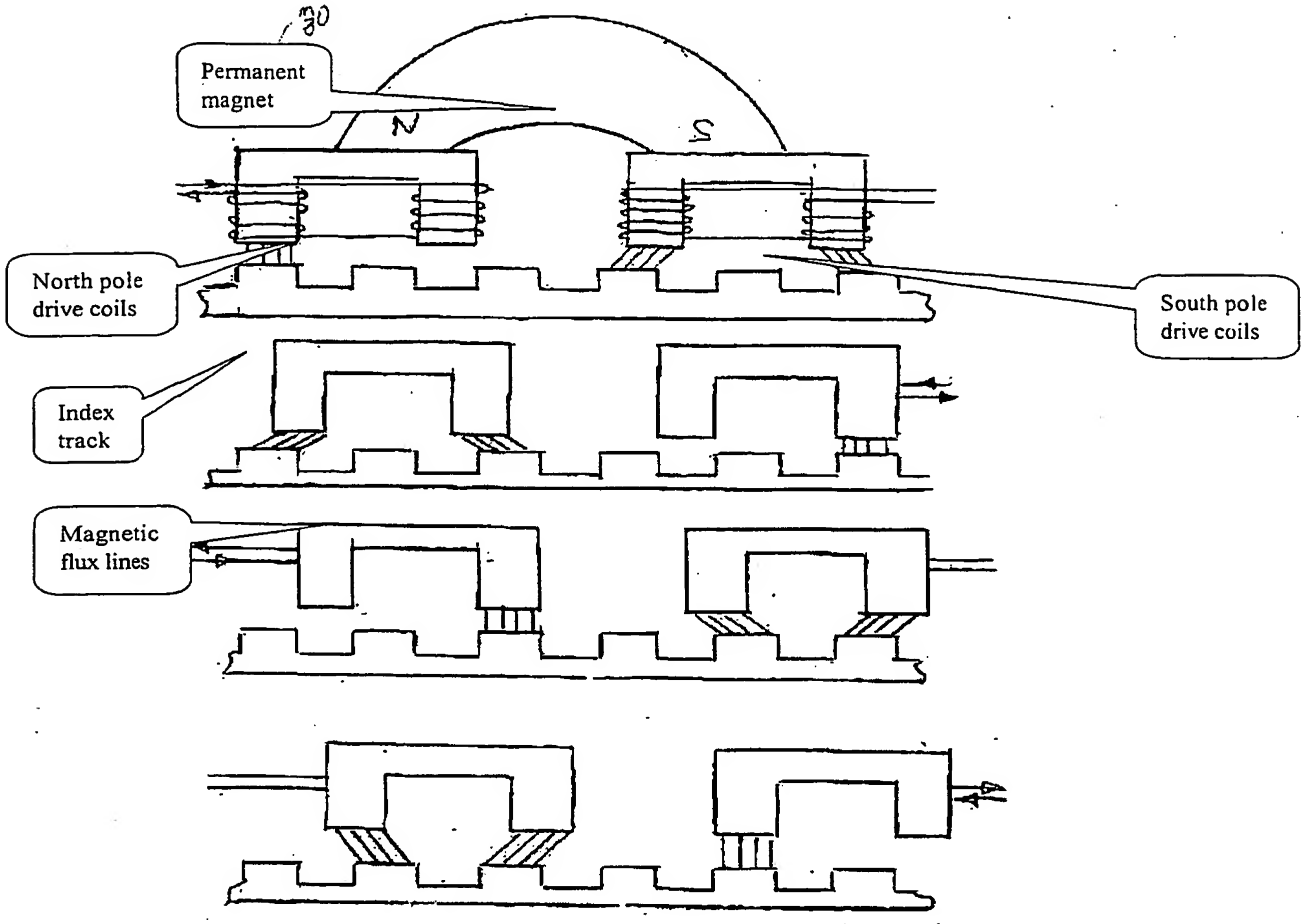
30
Permanent magnet
N
S
North pole drive coils
South pole drive coils
Index track
Magnetic flux lines

FIG. 5

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/31100

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) :H04N 5/232
US CL :348/211
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 348/211, 143, 151, 152, 159, 226, 211, 213, 214, 373, 468, 518; 340/541, 628; 315/133.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST: video camera, wireless, mutiple, mutiplex, electromecahnical, pan, tilt, light compensate, amplitude shift key, RF modulator, Internet, Sawyer linear motor.

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 5,517,236 A (SERGEANT et al.) 14 May 1996, Figs 1-2, col. 2, lines 10-67; col. 3, lines 1-20; col. 5, lines 35-50; col. 13, lines 55-67. | 1-31 |
| Y | US 5,128,755 A (FANCHER) 07 July 1992, Figs. 1-2, col. 1, lines 1-67; col. 4, lines 62-67. | 1-31 |
| Y | US 3,778,672 A (FOUNTAIN) 11 December 1973, col. 2, lines 1-6. | 23-29 |
| Y | US 5,793,420 A (SCHMIDT) 11 August 1998, col. 8, lines 10-20. | 25, 29 |
| Y | US 5,990,938 (BERN) 23 November 1999, Fig. 2, col. 4, lines 49-62. | 26 |

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
07 DECEMBER 2001

Date of mailing of the international search report
06 MAR 2002

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Form PCT/ISA/210 (second sheet) (July 1998)★

## INTERNATIONAL SEARCH REPORT

International application No.
PCT[illegible]1/31100

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 5,694,169 A (NOJI) 02 December 1997, see abstract. | 27 |
| Y | US 5,382,943 A (TANAKA) 17 January 1995 | 28 |
| A | US 4,860,101 A (PSHTISSKY et al. ) 22 August 1989, see entire document. | 1-31 |
| A | US 5,450,140 A (WASHINO) 12 September 1995, see entire document. | 1-31 |